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Breath-testing the savanna

Dr Joe Holtum of James Cook University is part of a team investigating the impact of rising carbon dioxide concentrations on savanna grasses and trees, and on the broader savanna ecosystem.

Australia's tropical savannas are the focus of world-first research into the effects of rising carbon dioxide levels on a natural tropical ecosystem.

Wendy Pyper reports.

At Yabulu, 25 kilometres north of Townsville, scientists from CSIRO and James Cook University (JCU) have ringed six, 15 metre-diameter plots of knee-high savanna grass and tree seedlings with a perimeter of piping and sophisticated electronic equipment.

For the next five years, this perimeter will regulate the flow of carbon dioxide (CO_2), piped across the plots from the neighbouring Queensland Nickel Pty Ltd refinery.

Three different concentrations of the gas – 370 parts per million (ambient), 460ppm and 550ppm – will be distributed via the wind across two plots each.

Then, at regular intervals, scientists will measure changes in plant performance, species composition, nutrient levels and carbon flow.

Dr Andrew Ash of CSIRO Sustainable Ecosystems says the project, called the Australian Free Air Carbon Dioxide Enrichment Study (OzFACE), will provide the first insights into the impact of rising CO_2 concentrations on savanna grasses and trees, and on the broader savanna ecosystem.

'CO_2 levels are likely to be 500–600 ppm by 2050, depending upon our global emissions of greenhouse gases,' Ash says.

Carbon counting

TROPICAL savanna grasses such as black spear grass (*Heteropogon contortis*), kangaroo grass (*Themeda triandra*) and golden beard grass (*Chrysopogon fallax*), have a different way of fixing CO_2 than trees and temperate grasses. They are called C4 grasses because they produce a four-carbon compound called oxaloacetate, during the conversion of CO_2 to starch and sucrose.

Trees, shrubs, temperate grasses, legumes and most forbes, on the other hand, have a C3 photosynthetic pathway. The first step in their conversion of CO_2 to starch and sucrose is a three-carbon compound called 3-phosphoglycerate.

In the present atmosphere, C3 plants lose up to 40% of the CO_2 fixed in photosynthesis to a process called photorespiration. As a result, they are less efficient than C4 plants. As CO_2 levels rise however, the efficiency of C3 plants will increase, because CO_2 directly inhibits photorespiration, causing C3 plants to grow faster.

The C4 plants will also benefit from higher CO_2 as their water use efficiency increases (see main story). Scientists anticipate that as CO_2 concentrations rise, the savanna system might become less prone to the effects of drought.

'This could have a range of effects, such as increased grass growth, a thickening woody layer, changes in competition between trees and grasses and changes in the flow of carbon through the system.

'During the next five years, this project will help us understand those impacts and allow us to assist land managers and graziers in the savannas to plan for the future.'

Ash and his JCU collaborator, plant physiologist Dr Joe Holtum, already have an inkling of what to expect, thanks to some earlier glasshouse experiments. These experiments involved growing savanna grasses in pots at ambient (370ppm) and high (700ppm) CO_2, under simulated wet and dry seasons.

'At the end of our trial, we found the control pots (ambient CO_2) had dried out at the end of the dry season. But pots under elevated CO_2 were still moist,' Ash says. 'The high CO_2 plants had also grown 30–40% more because they hadn't suffered drought stress.'

Ash says the reason for this increase in water use efficiency is that under high CO_2, the stomata (air breathing pores) in the leaves don't need to open as wide to take in CO_2. So the plants transpire (lose water) less. While this allows the grasses to grow more, Ash says their nutritional quality could be reduced in a nutrient-limited environment.

'The savanna soils are already low in nitrogen and phosphorus. So increased grass growth will probably reduce the concentration of compounds such as protein, and increase the concentration of fibre,' he says.

'And if temperatures rise, we might expect the nutritional quality to decline further, as higher temperatures stimulate faster growth and the accumulation of indigestible fibrous compounds.'

This outcome could have both positive and negative effects on the beef industry, a large proportion of which is supported by the savannas. 'You might be able to grow more and the grasses might be more drought tolerant, but animals might not do as well,' Ash says.

Today's grazing practices could also have an effect on the flow of carbon through the savanna system, affecting its capacity to act as a carbon sink.

The savannas contain 33% of Australia's terrestrial carbon, which is distributed between the trunks, stems, leaves and roots of the plants and within the soil and leaf litter. Preliminary carbon measurements at a number of overgrazed sites showed a 30–60% reduction in organic carbon in the top 10cm of soil. But Holtum says that when grazing practices are adjusted to account for changes caused by rising CO_2 this carbon loss could be reduced.

'If the tussock grasses remain green for longer, they could be lightly grazed for

The Townsville Bulletin

John Seedhouse of Queensland Nickel. Carbon dioxide from the nickel refinery is being piped across the experimental plots to simulate the effects of rising carbon dioxide levels on a natural tropical ecosystem.

longer during a season,' he says. 'That way you'd get more biomass and more carbon would be sequestered in the soil.

'This could be a win-win for graziers, as retaining more carbon in the soil is likely to be closely tied to maintaining a stable perennial grass forage supply which is good for sustainable beef production.'

Ash says that if overgrazing continues, however, soil carbon may decline, but the amount of carbon stored in trees could increase, as fires become less frequent (due to less fuel on the ground) and the woodland thickens.

To examine the interaction between grazing and changes in the savanna grasses, Ash and Holtum are conducting grazing simulations by clipping with secateurs the grass species favoured by cattle.

Another change to be examined during the project is the shift in plant composition. By measuring the growth and photosynthesis of trees and grasses, subtle changes in the interactions between grass species and between trees and grasses can be detected. One possible scenario is a thickening of the woody layer.

'We might expect spurts of growth in trees during the wet, and they might grow faster to a height where they're less affected by fire. So we could see a more wooded savanna,' Holtum says.

As well as more rapid growth, Holtum says that high CO_2 can stimulate the production of defence compounds in leaves. This could affect the balance between trees and the animals that graze on them.

'What will happen to the animals that eat a lot of leaves, such as koalas and possums? he asks? 'They may have to be more selective about the types of trees they eat, so the patches of trees they need to graze on might differ from those they graze on now.'

To answer these and other plant defence-related questions, Melbourne University's Dr Ian Woodrow – a specialist in the production of defence compounds by Australian native plants – will study the defence compounds in the vegetation growing at the OzFACE site.

Holtum, and Ash are looking to establish collaborations to examine other potential effects of rising CO_2, such as effects on soil microorganisms, and to coordinate the multitude of samples that need to be taken by scientists who will benefit from the research.

CSIRO's Dr Andrew Ash checks one of the experimental plots in the Australian Free Air Carbon Dioxide Enrichment Study. Ash says that plants increase their water use efficiency under higher carbon dioxide conditions because their stomata don't need to open as wide. Consequently they lose less water. This enhances plant growth, but can limit their nutrient content.

Abstract: Australia's tropical savannas are the focus of world-first research into the effects of rising carbon dioxide levels on a natural tropical ecosystem. Scientists involved in 'OzFACE', the Australian Free Air Carbon Dioxide Enrichment Study, are piping different concentrations of CO_2 over plots of savanna grasses and young trees, and measuring changes in plant performance, species composition, nutrient levels and carbon flow. Preliminary studies suggest a range of impacts could be expected, such as increased grass growth and drought tolerance, a thickening woody layer, and changes in competition between trees and grasses. Scientists are also looking at the effect these changes could have on grazing and the production of plant defence compounds in the leaves of trees.

Keywords: tropical savannas, savanna grasses, carbon dioxide, plant physiology, carbon stores, Australian Free Air Carbon Dioxide Enrichment Study (OzFACE).